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MSC-04440

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 71-FM-238

June 25, 1971

A METHOD FOR LUNAR ROVING VEHICLE POSITION DETERMINATION FROM THREE LANDMARK OBSERVATIONS WITH A SUN COMPASS

Mathematical Physics Branch
MISSION PLANNING AND ANALYSIS DIVISION

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PROJECT APOLLO

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By T. J. Blucker, Mathematical Physics Branch,
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SUMMARY

A simplified method is described for determining the position of the lunar roving vehicle (LRV) on the lunar surface during Apollo 15. The method is based upon sun compass azimuth measurements of three lunar landmarks. The difference between the landmark azimuth and the sun azimuth is measured and the resulting data are voice relayed to the Mission Control Center for processing.

INTRODUCTION

The Mathematical Physics Branch (MPB) is currently evaluating methods for LRV position determination using sun compass landmark sightings during Apollo 15 for crew contingency lunar surface navigation. This note defines one method being considered using sun compass azimuth measurements of three landmarks. The sun compass to be carried by the Apollo 15 crew may be used to measure the difference between the target landmark azimuth and the sun azimuth, and these data must be voice relayed to the ground for processing. This same method is used by surveyors to determine their position from measurements of the angles among three known points. While the surveyor would normally choose three points forming a triangle which contained his own position to simplify the computations, this is not a requirement. Use of this method will eliminate constant angular bias errors in the observations because only the azimuth differences are used.

DISCUSSION

The basis of this method is that the loci of positions from which two points, A and B, are separated by the measured angle γ are segments of circles in which $\overline{AB}$ is a chord with a central angle of 2γ if $\gamma \leq 90°$ or $360° - 2\gamma$ if $\gamma > 90°$. The measurement of the angle α between B and C will yield two more segments. These segments will intersect each other at four points other than the landmarks, but only one of these points will yield the proper azimuth to the three landmarks. (The method is simplified if the point from which the sightings are taken is located inside the triangle formed by the three landmarks. This eliminates the two segments outside the triangle, thus reducing the number of intersections from four to one.)

COMPUTATIONS

Given the coordinates and observed azimuths of three landmarks,

$$\underline{P}_n, \; A_{Zn} \qquad\qquad n = 1, 2, 3$$

the following calculations may be performed (fig. 1).

$$\alpha = \left| A_{Z_2} - A_{Z_1} \right| \qquad \text{If } \alpha > 180° \text{ set to } 360° - \alpha$$

$$\beta = \left| A_{Z_3} - A_{Z_2} \right| \qquad \text{If } \beta > 180° \text{ set to } 360° - \beta$$

$$\left.\begin{aligned} \underline{A} &= (\underline{P}_2 - \underline{P}_1)/2 \\ \underline{B} &= (\underline{P}_3 - \underline{P}_2)/2 \end{aligned}\right\} \quad \text{half chords}$$

$$\left.\begin{aligned} \underline{A}_N &= (A_y \underline{i} - A_x \underline{j})/\tan\alpha \\ \underline{B}_N &= (B_y \underline{i} - B_x \underline{j})/\tan\beta \end{aligned}\right\} \quad \text{normals to } \underline{A} \text{ and } \underline{B} \text{ with lengths equal to the distance of the circle center}$$

$$\left.\begin{aligned} \underline{C}_{A_1} &= \underline{P}_1 + \underline{A} + \underline{A}_N \\ \underline{C}_{A_2} &= \underline{P}_1 + \underline{A} - \underline{A}_N \\ \underline{C}_{B_1} &= \underline{P}_2 + \underline{B} + \underline{B}_N \\ \underline{C}_{B_2} &= \underline{P}_2 + \underline{B} - \underline{B}_N \end{aligned}\right\} \quad \text{centers of the circle segments}$$

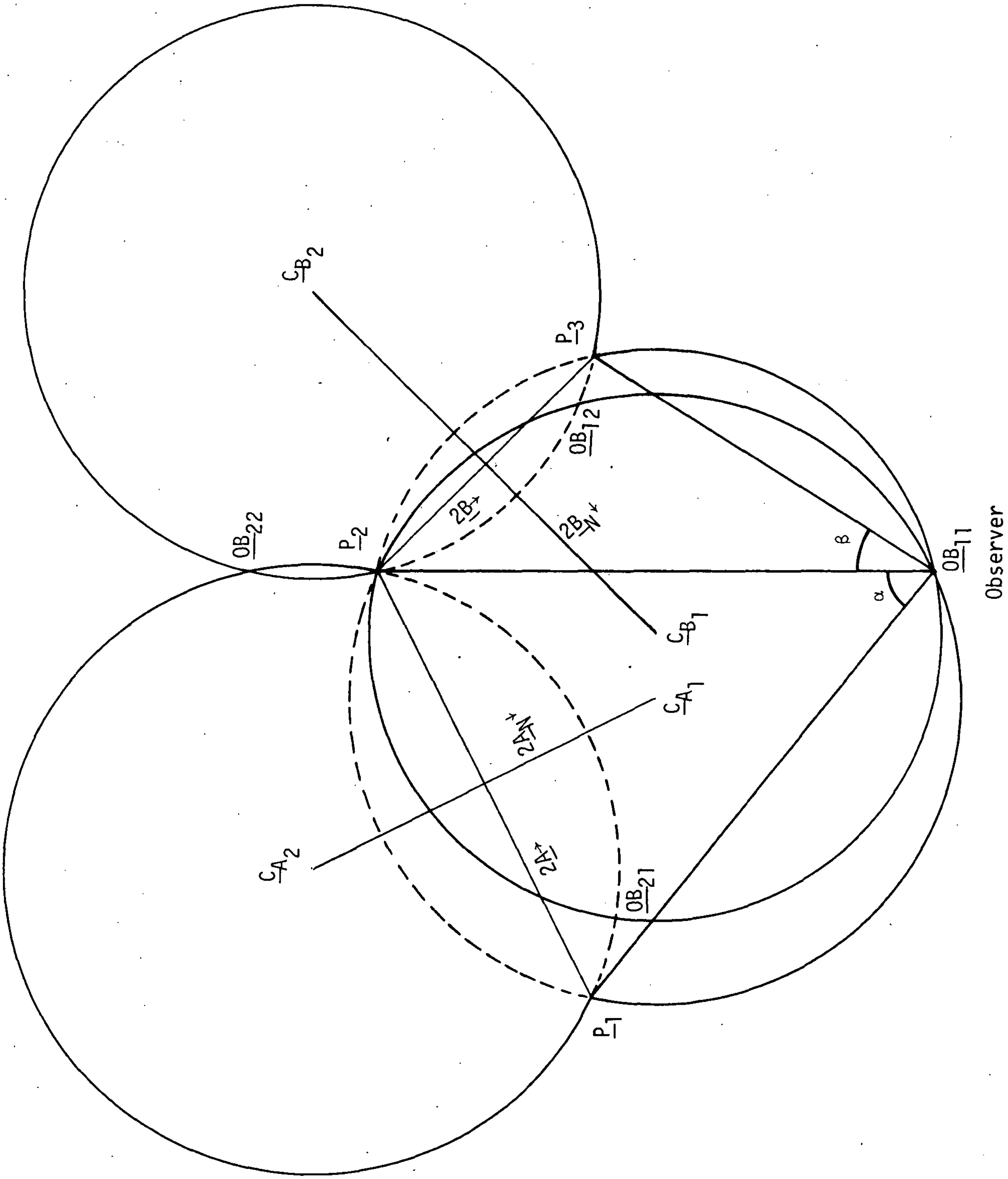
Since the circles about $\underline{C}_{A_n}$ and $\underline{C}_{B_m}$ intersect at $\underline{P}_2$, then the other intersection is symmetric about $\underline{C}_{B_m} - \underline{C}_{A_n}$

$$\underline{OB}_{nm} = \underline{P}_2 - 2\left\{\underline{P}_2 - \underline{C}_{A_n} - \left(\underline{C}_{B_m} - \underline{C}_{A_n}\right)\left[\left(\underline{P}_2 - \underline{C}_{A_n}\right) \cdot \left(\underline{C}_{B_m} - \underline{C}_{A_n}\right)\right] \Big/ \left|\underline{C}_{B_m} - \underline{C}_{A_n}\right|^2\right\}$$

If the azimuths of $(\underline{P}_i - \underline{OB}_{NM},\ i = 1,2,3)$ are all within the bias tolerance of A_{Z_i}, then $\underline{OB}_{nm}$ is the position of the observer. This contigency navigation method can easily be implemented to provide real-time ground support for Apollo 15.

CONCLUSIONS

A simplified method for computing the LRV position on the lunar surface using sun compass measurement during Apollo 15 has been presented. The landmark measurements made with the sun compass must be voice relayed to the ground for processing if this method is choosen to be used. The advantage of this method is that the constant angular bias errors in the measurements will be eliminated.



C_{B_2}
P_3
OB_{12}
$2\vec{B}$
$2\vec{B}_N$
OB_{22}
P_2
β
α
OB_{11}
Observer
C_{B_1}
C_{A_1}
$2\vec{A}_N$
C_{A_2}
$2\vec{A}$
OB_{21}
P_1